PACIFIC NORTHWEST CLIMATE IMPACTS RESEARCH CONSORTIUM (CIRC)
YEAR 2 PROGRESS REPORT

1. **Award Title: CIRC 2.0: Transforming Data into Usable Knowledge for Adapting to Climate Related Hazards in the Pacific Northwest (NA15OAR4310145)**
2. **Performance Period: June 1, 2016–May 30, 2017**
3. **Team Members**

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4. New Areas of Focus or Partnership

The activities of CIRC 2.0 are organized in a conceptual cube consisting of three streams, or core projects, each with three integrating components that together address three key climate risks and hazards facing the Pacific Northwest (fig. 1). The three streams are: (1) Climate and Water Toolbox; (2) Data Mining; and (3) Community Adaptation. The integrating components are: (a) Biophysical Science; (b) Social Science and Decision-Support Evaluation; and (c) Engagement and Outreach.

Each stream addresses one or more of the key climate risks areas (top face of cube) outlined in the Northwest climate assessment report "Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities" (Dalton et al., 2013). Key climate risks include: (i) impacts of warming on snowpack and resulting effects on hydrology and related hazards (e.g., drought, flooding, and landslides); (ii) consequences of changes in the coastal environment (e.g., erosion, flooding, and health); and (iii) cumulative effects of climate change on forest ecosystems and mortality (e.g., fire and drought). In year two of CIRC 2.0, we have advanced in each stream and integrating component while leveraging resources with new partners.

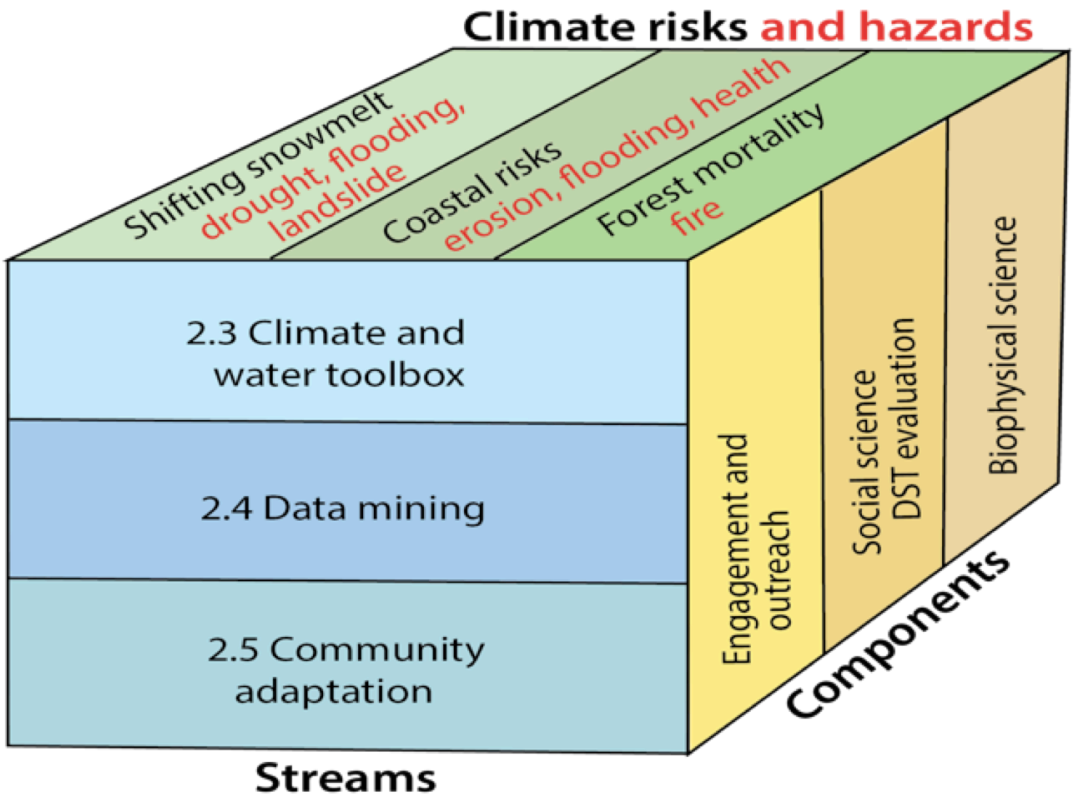

Figure 1: The CIRC 2.0 Cube

Climate and Water Toolbox Stream

Falling under the stream Climate and Water Toolbox, CIRC has been developing a series of free, online applications designed to aid our Pacific Northwest stakeholders as they plan for climate variability and change. We have bundled the products resulting from this effort into our Climate Tools, a broad category that we are using in our public representations and our websites. This category, intended for our stakeholders and applications' end users, combines every online tool CIRC has had a hand in developing as part of CIRC 1.0 and now CIRC 2.0. This includes online tools for CIRC 1.0 projects—including Integrated Scenarios and the Big Wood Data Explorer—as well as new CIRC 2.0 tools—including the Northwest Climate Toolbox and Climate Engine. During year two of CIRC 2.0, CIRC researchers Abatzoglou, Hegewisch, and Nijssen have improved several Climate Tools, key among these are the Climate Engine and Northwest Climate Toolbox.

Climate Engine

Climate Engine (http://climateengine.org) allows users to intuitively interact with high-resolution climate and remotely-sensed data by leveraging the technology behind the Google Earth Engine cloud-computing platform. Similar to Google Earth and Google Maps, Climate Engine's users can "zoom in" on a given locale. Once there, users can examine various climate factors (e.g., precipitation and temperature, drought, and wildfire risk) overlaid on the map in layers.

In year two of CIRC 2.0, Climate Engine's design and engineering were vastly improved. To make this happen, CIRC researchers worked with stakeholders, evaluating with them the design of Climate Engine's user interface. CIRC researchers also worked to significantly re-engineer elements on the tool's "backend," improving the tool's speed (including for real-time data uploading) and better integrating hydrologic and climate data in the tool's layering process. Climate Engine is now receiving daily data updates with the result that there is now only a 12-hour delay between collection of new data and incorporation into Climate Engine.

Northwest Climate Toolbox

In year two of CIRC 2.0, we launched the Northwest Climate Toolbox (https://www.climatetoolbox.org), a collection of web tools for visualizing the Pacific Northwest's past and projected climate and hydrology. Intended as an aid for decision-makers from farmers to forest managers concerned about managing drought and wildfire risk, the Toolbox integrates multiple climatological and hydrological datasets into a streamlined user experience.

While several tools were developed for the Northwest Climate Toolbox in year one of CIRC 2.0, several more tools as well as climatological and meteorological variables were developed and added to the Toolbox in year two. These include: new hydroclimate metrics (percentiles and departures from normal of soil moisture and snow water equivalent); a potential evaporation tool; more fire danger mapping layers; and a suite of climate-water decision-support tools created through the Regional Approaches to Climate Change—Pacific Northwest Agriculture (REACCH) project that CIRC inherited. The AgClimate Atlas tool was integrated into the Toolbox, leveraging funding from US Department of Agriculture Northwest Regional Climate Hub.

Less noticeable but nonetheless important, engineering efforts for the Northwest Climate Toolbox performed in year two included fully integrating layers of climate data from the University of Idaho and layers of hydrological data from the University of Washington into a common grid and platform. In order to achieve this, the Toolbox's downscaled, gridded climate datasets were expanded to include the Canadian portion of the Columbia River Basin (CRB) to match the domain of the hydrological datasets. The expanded climate datasets were then used to drive a hydrological model over the entire CRB. Results from this effort led to a study by CIRC researchers published in *Climate Dynamics* (Rupp et al., 2016).

CIRC researchers have presented the Northwest Climate Toolbox at multiple venues, including the American Geophysical Union Fall Meeting; the Northwest Climate Conference; several Pacific Northwest Drought Early Warning System webinars; a webinar with National Weather Service regional forecasters; and the Climate Impacts to Water, a Pacific Northwest-regional conference hosted by Washington State University Extension, the Center for Sustaining Agriculture and Natural Resources, REACCH, and Western Share Sustainable Agriculture Research and Education.

The Northwest Climate Toolbox is undergoing continuing user testing. This work leverages a related REACCH grant funded by USDA NIFA. In November 2016, CIRC researchers along with partners from the Northwest Climate Hub co-hosted a stakeholder focus group meeting in Coeur d'Alene, Idaho. The meeting's goals were to determine

what tools and data Pacific Northwest resource managers and other regional decision-makers are already using and to ascertain how the Toolbox and other CIRC Climate Tools might help fill information gaps.

User testing of the Northwest Climate Toolbox was conducted at the University of Idaho. In total, 70 hours of user testing videos were obtained from this effort. Videos are being analyzed and reviewed to help inform design and usability. To further aid this effort, analytics have been enabled on the Toolbox site. A web survey is also being designed to collect user information.

From this and other stakeholder feedback, CIRC team members Abatzoglou, Hegewisch, and Gilles are creating a series of video tutorials that will guide users through the various tools in the Northwest Climate Toolbox. These are being integrated with posts to CIRC's newsletter, *The Climate CIRCulator*, exploring the Toolbox's tools and how they might be used.

Plans are underway to continue to engage existing user groups, such as stakeholders from CIRC 1.0's Big Wood Basin Alternative Futures project, and new user groups—including regional weather forecasters and irrigators—to further evaluate the Northwest Climate Toolbox and facilitate its use among targeted groups. Interaction with CIRC Stakeholder Advisory Council member Hoekema from the Idaho Department of Water Resources resulted in the development of a new product for potential evapotranspiration to meet specific stakeholder needs.

The Northwest Climate Toolbox is identified in the Pacific Northwest Drought Early Warning System (PNW DEWS) draft strategic plan and is supported in part by National Integrated Drought Information System (NIDIS) Coping with Drought funding.

Data Mining Stream

CIRC's data mining stream is an experimental, exploratory research effort in which we aim to push the state of the science by developing new data mining and machine learning techniques to help identify hot spots of acute climatic vulnerability in the Pacific Northwest. By bringing together disparate types of data from climate and weather data to economic and social data, CIRC's data mining approach adds value beyond traditional data analysis. In year two, CIRC researchers Gessler and Seamon built a flexible and robust framework (dmine.io) to compile a plethora of data for exploration, mining, and metadata handling.

To make this process pertinent to CIRC's regional stakeholders, a stakeholder advisory committee for the project was convened. The committee includes attendees approached at the PNW DEWS launch in February 2016 as well as strategically chosen stakeholders. CIRC team members worked with stakeholders to identify a list of priority focus areas for the data mining stream, specifically around water availability. Priority focus areas included the demand side of hydrology (e.g., crop demand) and stream temperatures. CIRC is developing a prototype data mining capability seeking to identify connections between insured crop losses and various metrics of drought on the monthly timescale in the inland Pacific Northwest. Driving this preliminary analysis is the research question: What drought metrics are driving wheat crop loss claims and counts in the Palouse

region? Early results from this effort can be viewed on the project website. CIRC will continue to engage with stakeholders to provide further guidance and feedback.

Data mining to identify areas of water scarcity in the Pacific Northwest is identified in the PNW DEWS draft strategic plan and is funded in part by NIDIS Coping with Drought funding. The findings from this stream will help target activities and resources in the PNW DEWS and may also inform CIRC's plan to identify a second community for the Community Adaptation stream.

Community Adaptation Stream

During year two, the CIRC Community Adaptation effort that we refer to as the Grays Harbor Coastal Futures project (in Grays Harbor County, Washington) held two stakeholder workshops (June 6, 2016 and April 18, 2017) and several stakeholder webinars and surveys soliciting stakeholder input. During the June 2016 workshop, researchers and stakeholders refined a set of four policy scenarios—Baseline, Protect, Realign, and Restore—to assess the impact of climate change on local coastal communities, and organized technical working groups to foster continued stakeholder input. Using data from various sources, including that identified by various stakeholders, the CIRC team populated an integrated, agent-based model using the *Envision* computing platform to examine the impact of multiple stressors including different levels of climate change on the shoreline of Grays Harbor County. During the April 2017 workshop, researchers presented initial results organized around "storylines" designed to guide stakeholders through the various policy, planning, and climate scenarios suggested by the *Envision* modeling and their stakeholder input. Storyline topics included exploring changes to private property, public goods, and hazards. A rich conversation between stakeholders and CIRC researchers resulted from this interaction. In total, 75 unique comments were collected from stakeholders. The CIRC team is currently organizing its response on how to integrate these comments into the *Envision* modeling effort. (See section 12: ***Grays Harbor Coastal Futures: Policy Discussions, Policy Scenario Narratives, and Storylines.***)

The health component of the Grays Harbor Coastal Futures project moved forward in building a relationship with the Grays Harbor County Health Department. Initial climate-related concerns expressed by the Health Department include health outcomes from bay flooding, water quality, and disease burden. More stakeholder engagement around the health component is planned going forward. Calculations of heat and humidity related climate metrics relevant to human health were made for Grays Harbor County as well as some climate science translation summary of wildfire and smoke risk.

CIRC conducted surveys at all stakeholder meetings, collected participant observations during stakeholder interactions, and is analyzing results looking at co-production trends over time. A study comparing the decision-support processes of the CIRC 2.0 Grays Harbor Coastal Futures and earlier CIRC 1.0 Tillamook Coastal Futures projects found that the stakeholder process in the two coastal communities were similar, but nonetheless showed key differences.

In Tillamook County, widespread chronic erosion and concern about beach access for residents and tourists guided the co-production process. In Grays Harbor County, hotspot erosion after the 2015–2016 El Niño framed the conversation for the outer coast, while

concern about flooding and loss of critical habitat for birds, oysters, and razor clams were the most important concerns around the bay. As a result, the Grays Harbor project is exploring more "green" coastal adaptation strategies, such as rebuilding dunes and conserving habitat. As the Grays Harbor project concludes a more complete comparison between the projects will be made, exploring processes and results.

In response to stakeholder concerns, the Grays Harbor project is leveraging funding to improve inner bay flood modeling in Grays Harbor. The Quinault Indian Nation, with funding from the Bureau of Indian Affairs, has contracted with CIRC researcher Ruggiero to assess the impact of coastal flooding on infrastructure, including within and upstream of Grays Harbor. Along with CIRC funding to hire a new graduate student, this leveraged work will be used to develop a more sophisticated flood model to assess inner bay flooding impacts in Grays Harbor.

Additional New Foci

During year two, CIRC engaged in additional synergistic partnerships, including a project to produce an adaptation guidebook for tribes, partnering with USDA Regional Climate Hubs on decision-support tool evaluation, coordinating drought indicators and impacts across the region, and the Fourth National Climate Assessment.

Tribal Adaptation Guidebook

The Oregon Climate Change Research Institute, CIRC's home at Oregon State University, received funding from the North Pacific Landscape Conservation Cooperative to develop a tribally-focused, next generation adaptation guidebook to support tribes in addressing tribal priorities through climate adaptation planning. Several CIRC team members are involved in the project.

Partnering with USDA Regional Climate Hubs on Decision-Support Tool Evaluation

Spurred by participation in CIRC's webinar series on Decision-Support Tool Evaluation (see section 10: ***Evaluating Decision-Support Tools Webinar Series***), the USDA Northwest Regional Climate Hub is engaging CIRC researcher Hartmann and CIRC co-lead Lach to participate in a workshop and white paper on coordinating best practices and frameworks for evaluating decision-support tools and resources among the USDA Climate Hubs, NOAA RISAs, DOI CSCs, and LCCs. One of CIRC's past tools or processes may be highlighted as a case study.

Coordinating Drought Indicators and Impacts

With potential additional funding from NIDIS, CIRC plans to work with the National Drought Mitigation Center (NDMC) and the Western Regional Climate Center during Fall 2017 to develop common drought indicators to explore and compare drought impacts across Oregon, Washington, Idaho, and Montana. This effort is the result of a meeting held September 2016 in Boise, Idaho, which explored the challenges of responding to the widespread western drought.

Fourth National Climate Assessment

CIRC co-lead Mote and program manager Dalton are authors of the Northwest chapter of the Fourth National Climate Assessment (NCA4). See Appendix A for more details on CIRC's involvement in the NCA4.

5. States Using CIRC Climate Services

All

- In September 2016, CIRC researcher Dello helped coordinate a regional drought-planning meeting in Boise, Idaho in conjunction with NIDIS and NDMC that included key state drought stakeholders and state coordinators. Drought coordinators from the Northwest states—Washington, Idaho, Oregon, and Montana—all agreed to approach drought in a similar way (e.g., coming up with similar indicators, triggers). The proposed metric project would begin fall 2017.
- All four Northwest states use CIRC's Pacific Northwest drought monitor in various capacities in early drought decisions.

Oregon

- Dello used figures from CIRC's Northwest Climate Toolbox in a briefing for the Oregon Senate and House.
- The Third Oregon Climate Assessment Report (2017), a state-mandated report led by Dalton, included figures from CIRC's Northwest Climate Toolbox.
- Dello has engaged several communities in eastern Oregon incorporating them into the PNW DEWS network.
- CIRC extension climate specialist Stevenson has engaged Oregon Master Naturalists, Oregon food producers, and the extension community in Oregon's Klamath Basin.

Washington

- The Washington Department of Ecology's Grays Harbor Shoreline Master Program is using data from the Grays Harbor Future Explorer in an appendix to a document guiding coastal decision-making. (See section 12: ***Grays Harbor Coastal Futures: Policy Discussions, Policy Scenario Narratives, and Storylines***.)
- Following a short presentation during the PNW DEWS February 2017 webinar about CIRC's Northwest Climate Toolbox by CIRC researcher Abatzoglou, the Washington Department of Ecology asked Abatzoglou to present the Northwest Climate Toolbox to the agency.
- Dello informally consults with Washington Department of Ecology staff on drought and climate matters.

Idaho

- Stevenson has engaged several communities in Idaho through the US Forest Service Intermountain Adaptation Planning, the Idaho Agriculture Summit, and junior groundwater holders from CIRC 1.0's Big Wood Basin Alternative Futures project.
- Stevenson serves on the Natural Resources Conservation Service's Idaho advisory committee.

Western Montana

- CIRC invited Ada Montague from the Montana Department of Natural Resources & Conservation to join CIRC's Stakeholder Advisory Council.

6. CIRC's Overall Program Impact

A. Evaluation Model

CIRC started a new database to record stakeholder engagement using a standard reporting template with the goal of collecting data on and tracking participation and facilitating network analysis. The survey tracks changes in communities over time as a way to start building networks. The survey itself has been streamlined so that researchers and stakeholders can complete it in about half a minute. The survey also helps determine the level of understanding stakeholders have of CIRC's presentations during stakeholder interactions throughout the project period.

CIRC researcher Hartmann has been working with each stream to create a decision-support tool (DST) evaluation plan rooted in a variety of evaluation frameworks. The DST evaluation frameworks include: A) decision-maker and user perspective comprising usability, suitability, and utility; B) technology sustainability within the climate application enterprise comprising sustainability, transferability, and interoperability; and C) an academic research perspective. As part of this effort, CIRC organized a webinar series, "Evaluating CIRC's Decision-Support Tools," to discuss best practices and challenges within these frameworks (see section 10: ***Evaluating Decision-Support Tools Webinar Series***). Tangible outcomes from the webinars include the development of a communication and design style sheet and a checklist of considerations for CIRC Climate Tools and communications.

CIRC graduate student Sokolovska is currently assessing the impact of the RISA program on graduate students associated with the program. Her project is exploring the following research topics: 1) How participation in co-production of knowledge affects participants' behavior and practice as scientists; 2) Kinds of capacities co-production projects help build for participants; and 3) How participation in co-production affects the participants' careers.

B. Summary of Results

As part of CIRC's effort in Grays Harbor County, Washington, CIRC graduate student Andrepont tallied the results of two surveys of stakeholder participants. Of the project's roughly 80 participants, 34 individuals participated in the two surveys. According to the tallied responses, a majority of respondents stated that they felt that the project was on track to produce results (i.e., actionable knowledge) that they would be able to put to work in their individual lives (82%) and their organizations (74%). Three-quarters (76%) of respondents reported that they felt that CIRC's collaborative research approach (i.e., the co-production of knowledge) has increased their understanding of coastal hazards both present and future in Grays Harbor County. Survey respondents also reported that they were likely to share the information they learned with their professional colleagues (74%) and people they know socially (59%).

CIRC researcher Hartmann has provided input to CIRC researchers about the tools they are developing. Hartmann has provided suggestions specific to the Northwest Climate Toolbox and has also worked with the team overseeing the UW Drought Monitoring System for the Pacific Northwest. Hartmann is currently working with teams developing two CIRC Climate Tools: the *Envision*-based interface for Grays Harbor Coastal Futures and CIRC's Data Mining effort. Hartmann also consulted with CIRC researcher Bachelet at the Conservation Biology Institute (CBI) on a CBI tool intended for Pacific Northwest resource managers. Meetings and consultations reviewed sustainability, transferability, and interoperability, among other concerns.

In March 2017, CIRC user-tested eight tools in the Northwest Climate Toolbox. The user testing was performed utilizing over 70 student participants at the University of Idaho through funding and resources provided by the REACCH project. Analysis of these user tests has highlighted how the tools could be improved. Planned improvements include: 1) modifying site language for a broader audience; 2) providing collapsible layers of information about the datasets and variables to cater to different users' needs and familiarity with the science; and 3) providing more detailed guidance on how to interact with the graphics.

7. CIRC's Influence on Building the Region's Adaptive Capacity

CIRC is increasing the capacity of local and regional decision-makers to prepare for and adapt to climate variability and change through our collaborative research approach of building knowledge-to-action networks and through our stakeholder-driven free, online interactive tools.

Throughout CIRC 1.0, CIRC built networks of stakeholders and created venues supporting conversations about planning. The legacy of these efforts can be seen in Idaho's Big Wood River Basin where our project stakeholders are now applying lessons learned from our work with them in their water management (see section 12: ***Implementing long-term policy scenarios elements in short-term drought decisions***). By the end of year two of CIRC 2.0, we have built a similar network of stakeholders in Grays Harbor County, Washington.

The development and growth of CIRC 2.0's suite of tools during the past year is enabling practitioners to communicate key messages about climate events to the public and we are seeing preliminary conversations about incorporating CIRC tools into operational forecasting. NOAA's National Weather Service (NWS) Storm Prediction Center has communicated on Twitter using Northwest Climate Toolbox fire danger maps. NOAA's NWS Forecast Office in Pendleton, Oregon has inquired about the using Toolbox tools in its forecasting. Representatives from CIRC's host organization, the Oregon Climate Change Research Institute, have shown the Toolbox to State of Oregon officials. Since 2011, the West Wide Drought Tracker (Abatzoglou et al., 2017), a cross-RISA project involving CIRC, California Nevada Climate Application Program, and the Western Regional Climate Center, provides easy access to fine-scale drought monitoring and climate products used by a variety of stakeholders, including the NWS, National Center for Environmental Information, state climate offices, and NIDIS, for research, outreach, communication, and data visualization.

8. Proud Accomplishment

In year two of CIRC 2.0, CIRC launched the Northwest Climate Toolbox (https://www.climatetoolbox.org). The Toolbox transforms raw climatological, meteorological, and hydrological information into a series of easy-to-navigate tools that allow users to plug in their location on a map and visualize data for that location. Tools in the Toolbox include visualizations of historical data (going back decades); short-term, seasonal forecasts (weeks to months); and long-term, future projections (decades to 2100). Additional tools track wildfire danger and how plant-growing zones are expected to shift as the climate warms. The Northwest Climate Toolbox's fully functional web interface with its multiple working tools is updated daily with CIRC data and hydrological layers.

We are proud of this accomplishment for the utility the Northwest Climate Toolbox provides to Pacific Northwest stakeholders. This project was designed specifically with Pacific Northwest farmers as well as forest and water managers in mind, and is intended to help our region respond to and prepare for potentially costly impacts to our region's agriculture and natural resources both today and under future climate change. And, still in its infancy, the project is already garnering lots of interest. The Toolbox also comes as a verification of CIRC 2.0's "streamed" approach. The Toolbox incorporates several CIRC teams at multiple universities, employing a production process built on the cooperation of our CIRC researchers, the lessons we've learned while working and publishing together, and the relationships and science that have resulted. In this way, the Toolbox effectively builds on the research, databases, stakeholder engagement, and social capital built by our team in CIRC 1.0, allowing us to effectively leverage earlier efforts. A joint effort between CIRC and our colleagues at the Northwest Knowledge Network, USDA Northwest Climate Hub, and US Department of Agriculture National Institute of Food and Agriculture, the Toolbox also shows CIRC's ability to leverage funding. But beyond all that, the Toolbox is a useful product not only for stakeholders but also for CIRC. We are using Toolbox results in public presentations while we are working to improve the Toolbox with new data, better user interfaces, and better communications and feedback from our end users.

9. Research Findings

Future snow decline in the Pacific Northwest

Rising temperatures in the Pacific Northwest are changing our region's hydrology, causing precipitation to fall more as rain and less as snow. This change has already led to water scarcities in the region. A recent publication in *Climatic Change* by CIRC researchers projects these changes into the future for our region. The study finds that by the year 2100, April 1 snowpack in the Pacific Northwest's Cascade Mountains is expected to decline by as much as 65% under current warming trends (Representative Concentration Pathway 8.5) (Gergel et al., 2017).

West Coast's 2015 record snow drought exacerbated by anthropogenic warming

As noted above, rising temperatures in the Pacific Northwest are causing precipitation to fall more as rain and less as snow. The year 2015 was the worst year on record for snowpack across the entire Western United States. Water year 2014–2015 saw record low snowpack measurements at 80% of mountain sites, upsetting earlier records set in 1977, according to a key CIRC research finding published in the journal *Geophysical Research*

Letter. Another key finding from the article is that anthropogenic forcing added about 1 degree Celsius (1.8 degree Fahrenheit) of extra warming to the water year 2014–2015 (Mote et al., 2016).

Anthropogenic warming linked to increased wildfire risk in Western US

Rising temperatures projected under future climate change are expected to make conditions ideal for larger, more destructive wildfires in the Pacific Northwest. These fires are expected to damage property and lead to significant change in our regional ecosystem. A study published in the *Proceedings of the National Academy of Sciences* and led by CIRC researcher Abatzoglou concludes that a climate change fingerprint is already observable in the recent growth in wildfires across the US West. The study finds that over half (55%) of the increase in fuel aridity conditions, a leading cause of wildfires, in recent years (1979 to 2015) is due to anthropogenic climate change (Abatzoglou and Williams, 2016).

Future climate in the Columbia River Basin

Ratified in 1964, the Columbia River Treaty between the United States and Canada is currently up for renegotiation. The treaty defines rights and responsibilities between the two countries concerning hydropower and flood control. Because climate change is expected to impact these and other demands on the Columbia River system by affecting the region's hydrology, any effective renegotiation of the treaty is very likely to include climate change projections. As part of a projected funded in part by the Bonneville Power Administration to support eventual inclusion of climate change in Treaty negotiations, CIRC researchers Rupp, Abatzoglou, and Mote conducted a study to determine the projected future climate of the Columbia River Basin (CRB) under various climate models and scenarios. They published their work in the journal *Climate Dynamics*. They found that by the later decades of this century (2070 to 2099), mean summer temperatures in the CRB are expected to reach 3 degrees Celsius (5 degrees Fahrenheit) above the baseline years 1979 to 1990 under the moderate warming scenario RCP 4.5, and 6 degrees Celsius (11 degrees Fahrenheit) above the baseline years 1979 to 1990 for the high warming scenario RCP 8.5 (Rupp et al., 2016).

Creating shared knowledge through knowledge-to-action networks

The uncertainties associated with future climate change make it difficult, if not impossible, for communities to make long-term decisions. A problem-solving strategy involving the creation of a knowledge-to-action network in the Big Wood Basin of Idaho is explored by CIRC co-lead Lach in a new book*, New Strategies for Wicked Problems* (Weber et al., 2017). One finding suggests that as decision-makers grapple with increasingly complex problems, approaches for integrating (rather than eliminating) uncertainty and extending the peer community to those who use the information, may be an equitable and efficient use of scientific data in situations that are not conducive to traditional approaches (Lach, 2017).

10. Communications and Outreach Activities

CIRC's communication efforts link our websites, newsletter, and social media accounts into an integrated user experience designed to promote our efforts and clarify the complexities of climate science for our stakeholders.

CIRC's Newsletter

Since 2012, CIRC has published our periodic newsletter, *The Climate CIRCulator (https://climatecirculatororg.wordpress.com*). A promotional tool meant to elevate the profile of CIRC's efforts, the *CIRCulator* also encourages informal science education covering climate science and climate impacts in the Pacific Northwest. This strategy—as well as the communication style—is informed by social science research that suggests climate science boundary organizations need to thoroughly explain their methods and assumptions as well as define specialty terms used in their research. The *CIRCulator* provides summaries of peer-reviewed climate and social science research covering climate research and climate adaptation pertinent to the Pacific Northwest.

This year CIRC communications specialist Gilles created the updated website for the *CIRCulator*. This reorganization reflects current standards typical of mainstream science and technology-oriented publications, such as *Wired* and *Scientific American*. Distribution of the *CIRCulator* integrates CIRC's direct email distribution with our new *CIRCulator* website and social media accounts. A complete *CIRCulator* archive is now available and categorized for easy search. This includes highlights of CIRC projects and publications. Distribution and readership of the *CIRCulator* and other CIRC social media is described in Figure 2.

CIRCulator Metrics (averaged per issue May 2016–2017)

- 1,635 *CIRCulator* email subscribers
- 400 opens and websites visits per email blast
- Three page views per visitor
- This 25% email open rate exceeds industry average (16.35%) for similar groups
- 12 percent email click rate (industry average 2.5%)
- 700 page views per issue, extra traffic appears to come from social media referrals
- *CIRCulator* stories and reviews have been picked up by the Associated Press, *Climate Central*'s blog *WXShift*, and Oregon State University's science newsletter *Terra*.

Social Media Metrics

- 1,142 (CIRC followers on Twitter)
- 202 (CIRC followers on Facebook)

Figure 2: CIRC Communication Metrics

CIRC's New Website

In 2016, CIRC's website was completely redesigned and rewritten (http://pnwcirc.org) to reflect a communications standard employed by high technology firms interested in conveying an informative but informal voice when interacting with end users. Organization of our resources underwent a reworking to make it easier for end users to navigate and find actionable information. New content rewrites strove whenever possible to be inclusive in their representation of our diverse stakeholders and their needs. This was done, for instance, by grounding our descriptions of climate impacts in what are real concerns about current and potential changes to regional cultures and livelihoods we have heard expressed in interactions with stakeholders.

To promote and explain our science, CIRC's new website contains an Our Science section, which includes a multi-page description of our research findings around climate

impacts; the assumptions and methods our research has employed; and conversational explanations of frequently used specialty terms found in that work (e.g., RCP, GCM, and downscaling). The content for the Our Science section was written almost entirely from CIRC research that was published in peer-reviewed journals.

Big Wood Video Project

At the request of RISA project leads, CIRC is participating in the creation of a video narrative designed to promote the efforts of CIRC and the other NOAA RISA Teams. In 2016, CIRC's video proposal concerning our work in Idaho's Big Wood Basin was selected for this effort. Currently in production, the video narrative will highlight CIRC's Big Wood Basin Alternative Futures Project, a stakeholder-driven community adaptation effort created to help local residents and business owners adapt to potential water scarcities as the climate changes throughout this century. As part of this project and to aid the filmmakers, CIRC identified filming locations and narrative themes, as well as interview subjects (stakeholders from CIRC's effort). CIRC team member Stevenson traveled to Idaho's Big Wood Basin with the filmmakers to film the project and work with the film's subjects.

Evaluating Decision-Support Tools Webinar Series

In the fall of 2015, CIRC embarked on an ambitious new effort by developing a series of free, online applications. We are presenting this effort to our stakeholders as our Climate Tools. To help our team members, as well as help others doing similar work, CIRC organized a webinar series during spring 2017 entitled, "Evaluating CIRC's Decision-Support Tools." Presented by CIRC researcher Hartmann, the webinars have reviewed best practices for climate change decision-support evaluation as well as basic concerns and obstacles tool designers might have.

Topics covered include communication strategies and field-testing; strategies and tactics for working with and designing for decision-makers; strategies and tactics to support decision-support tools beyond their funding; strategies to help integrate one's decision-support tool into the work of decision-makers; and how to get stakeholders to choose one's tool. While targeted toward the CIRC team and suite of tools, we invited participants from other RISAs, Climate Science Centers, and US Department of Agriculture Climate Hubs, as this is a topic of common interest among climate service providers. The first webinar had 62 attendees. The webinars, which were hosted by the Conservation Biology Institute (a CIRC partner), can be viewed at https://consbio.org/products/webinars/. Prompted by this webinar series, CIRC is currently developing a design style sheet and a checklist of considerations for decision-support tool developers.

Pacific Northwest Drought Early Warning System Webinars

CIRC co-convened a bi-monthly climate and drought outlook webinar series with the USDA Northwest Regional Climate Hub, the National Weather Service, and other partners. The webinar maintains a consistent format with a NIDIS introduction, a climate update from one of the state climatologists, a NWS outlook, a research topic relevant to the DEWS, and a USDA Climate Hub update. The group held webinars in July and October 2016, and February, April, and June 2017. Recordings are available on the

NIDIS website (https://www.drought.gov/drought/calendar/webinars). Participation in the October webinar reached capacity at 100 participants. The webinars are more popular in drier times, but 40 participants tuned in for the April webinar in the middle of one of the wettest starts to the water year on record. The webinars are advertised on the CIRC and PNW DEWS list serves, and the @NIDIS and @PNWclimate Twitter accounts.

11. Key Publications

Gergel, Diana R., **Bart Nijssen**, **John T. Abatzoglou**, Dennis P. Lettenmaier, and Matt R. Stumbaugh. "Effects of climate change on snowpack and fire potential in the western USA." *Climatic Change* 141, no. 2 (2017): 287-299.

> Employing ten 21st-Century climate scenarios, this paper examines projected snowpack declines and their implications for spring melt timing, soil moisture, and wildfire potential for five mountain ranges across the Western United States. The study's authors included CIRC researchers Nijssen and Abatzoglou. Other authors included former CIRC researcher Lettenmaier and former CIRC graduate student Stumbaugh. Mountain ranges reviewed in this study include Oregon and Washington's Coast and Cascade Ranges as well as Idaho and Montana's Northern Rockies. The climate scenarios coupled with the VIC hydrologic model showed a depletion of mountain snowpack across all mountain ranges, leading to a reduction in summer soil moisture and an increase in the potential for wildfires except at lower elevations where fuel loads are limited.

Inouye, Allison M., **Denise H. Lach**, **John R. Stevenson**, **John P. Bolte**, and Jennifer Koch. "Participatory Modeling to Assess Climate Impacts on Water Resources in the Big Wood Basin, Idaho." In *Environmental Modeling with Stakeholders*, ed. by Steven Gray et al. 289–306. Springer International Publishing, 2017. doi: 10.1007/978-3-319-25053-3_14.

> In this chapter of the book *Environmental Modeling with Stakeholders*, CIRC co-lead Lach and team members Stevenson and Bolte describe CIRC's efforts creating a knowledge-to-action network in Idaho's Big Wood Basin. The chapter reviews in detail how CIRC went about creating the stakeholder-driven community adaptation effort, what it means to co-produce science with the help of local residents and business owners, and how to discuss issues around water scarcity and climate.

Mote, Philip W., **David E. Rupp**, Sihan Li, Darrin J. Sharp, Friederike Otto, Peter F. Uhe, Mu Xiao, Dennis P. Lettenmaier, Heidi Cullen, and Myles R. Allen. "Perspectives on the causes of exceptionally low 2015 snowpack in the western United States." *Geophysical Research Letters* 43, no. 20 (2016). doi: 10.1002/2016GL069965.

> Led by CIRC co-lead Mote and including CIRC researcher Rupp and former CIRC researcher Lettenmaier, this paper puts numbers on the Pacific Northwest's recent "snow drought." Reviewing decades of mountain snowpack data measuring snow water equivalent (SWE) from roughly 1,800 recording sites across the West Coast, the researchers found that during the 2014–2015 water year, 80 percent of mountain snowpack sites showed record low SWE levels. This paper also used a distributed computing effort called *weather@home* to run simulations of a regional climate model on volunteers' computers to determine the likely climatic factors leading to the snow drought. The researchers conclude that anthropogenic climate change added about 1 degree Celsius (1.8 degree Fahrenheit) in extra warming to the 2014–2015 water year leading to the snow drought.

Serafin, Katherine A., **Peter Ruggiero**, and Hilary F. Stockdon. "The relative contribution of waves, tides, and nontidal residuals to extreme total water levels on US West Coast sandy beaches." *Geophysical Research Letters* 44, no. 4 (2017): 1839-1847.

> This paper seeks to understand how tides, waves, and other coastal processes combine, producing flooding and erosion that threaten coastal communities. Led by CIRC graduate student Serafin and including CIRC researcher Ruggiero, this paper examines the relative contribution of individual coastal processes in the creation of extreme total water levels (TWLs) along the sandy beaches of the US West Coast. The paper found that extreme TWLs differed markedly from California in the south to Oregon and Washington in the north. Understanding the regional variability of TWLs is expected to lead to a better understanding of how sea level rise, changes in storminess, and possible changes in the frequency of major El Niño or La Niña events may impact future coastal flooding and erosion along the US West Coast and elsewhere.

Stevenson, John, Michael Crimmins, Jessica Whitehead, Julie Brugger, and Clyde Fraisse. "Connecting Climate Information with Practical Uses: Extension and the NOAA RISA Program." In *Climate in Context*, ed. Adam S. Parris et al. 75–98. John Wiley and Sons, 2016, doi: 10.1002/9781118474785.

> In this chapter of the book *Climate in Context*, CIRC extension climate specialist Stevenson and colleagues review case studies of NOAA RISA program and university Extension collaborations and how these collaborations have helped build knowledge-to-action networks (KTANS) and resulting actionable science used to inform climate adaptation. Describing CIRC's own RISA-Extension KTAN effort in Idaho's Big Wood Basin as well as other instances of RISA-Extension collaboration, Stevenson and colleagues outline what has worked well in these collaborations and how these collaborations might be expanded in the future. The chapter also describes how these collaborations have been informed by key themes underlying RISA, Extension, and similar boundary organizations.

12. Plans, Policies, Strategies, Tools, Agreements resulting from CIRC Work

Grays Harbor Coastal Futures: Policy Discussions, Policy Scenario Narratives, and Storylines

In spring 2017, the CIRC Grays Harbor team was approached by representatives of the Grays Harbor County Shoreline Master Program, a project overseen by the Washington Department of Ecology, about using data from CIRC's Grays Harbor Coastal Futures project as an appendix to an official document guiding coastal decision-making. As of June 2017, a draft of this document was in review.

This work comes as part of a collaboration between the CIRC team and Washington state and local officials to discuss the impacts of existing, or modified, land-use policies under various climate change and population growth scenarios as a way to protect the state's coastal populations and properties from coastal hazards. These talks have included how the state's policies regarding the use of hard and soft engineering structures (e.g., riprap revetments, beach nourishment, and related infrastructure) could be modified or altered as a response to projected sea level rise. Results from these productive talks have in turn informed the CIRC team's engagement with stakeholders in Grays Harbor County.

In year two of CIRC 2.0, CIRC team members working with local stakeholders developed and presented *Storylines* and *Policy Scenario Narratives* from the Grays Harbor Coastal Futures project to the project's stakeholders. Informed by both talks with

Washington state and local officials and hours of stakeholder engagement employing the knowledge-to-action network (KTAN) co-production model, the Policy Scenario Narratives act as a way to clearly visualize the results of the co-production process in Grays Harbor County, and the actionable science that has resulted. The Policy Scenario Narratives do this by employing the *Envision* computer-modeling platform developed by CIRC researcher Bolte and used extensively in CIRC 1.0, including on the Big Wood Basin Alternative Futures project. Through *Envision*, the CIRC team was able to combine current state-of-the-science projections of climate change variability (incorporating waves, El Niño-Southern Oscillation events, and regional sea level rise) with projections of future human population growth and the economic and infrastructural development associated with it.

Policy Scenario Narratives chosen by the KTAN: *Baseline*, an exploration of what continuing present day policies would look like when compared to projections for sea level rise and other hazards; *Realign*, an exploration of policies and/or decisions that involve changing human activities to suit the changing environment (e.g., relocation of infrastructure and/or people); *Protect*, an exploration of policies or decisions that involve resisting environmental changes in order to protect existing infrastructure and human activities (e.g., building or strengthening shoreline armour); and *Restore*, an exploration of policies and/or decisions that accommodate environmental change and prioritize habitat protection and conservation (e.g., restore dunes or nourish beaches).

The CIRC team also developed and made available online a series of *Storylines* that organize the scientific and model assumptions that guided the project's initial questions and results underlying the Policy Scenario Narratives. The guiding Storylines include: development (exploring questions about development patterns and population growth in Grays Harbor County); public good (exploring questions about beach accessibility, hazard response costs, and road hazard risks); and property risk (questions about building hazards, backshore protection structures, dune restoration projects, and beach nourishment). As with the Policy Scenario Narratives, the Storylines include questions and initial results guided by the KTAN's concerns and priorities identified earlier in the project.

Implementing long-term policy scenarios elements in short-term drought decisions

At the time of filing this report in June 2017, junior water right holders in the Big Wood Basin of central Idaho were responding to a "water call" from senior water holders in the region. Following on the heels of several poor snowpack years, the water call requires that junior right holders mitigate water shortages experienced by senior users through conserving water. If these junior water users fail to sufficiently mitigate, they will face curtailment of the water they rely on to produce crops, potentially leading to economic losses for the junior holders. Junior holders are experimenting with several strategies modeled in CIRC's Big Wood Alternative Futures project and our related online tool, the Big Wood Data Explorer (http://explorer.bee.oregonstate.edu/Topic/BigWood/Default.aspx).

As with other CIRC projects that use the knowledge-to-action model, the Big Wood project combined stakeholder concerns around climate issues (in this case water scarcity) with other variables (e.g., a range of potential climate and population changes with

resulting land and water use changes) to create a series of policy scenarios that could be used to adapt to the impacts of the changes. For Big Wood, that meant creating with stakeholders a series of actions—from policy decisions to changes in farming practices—that Big Wood community members could use to make their basin more resilient in the face of change.

CIRC climate extension specialist Stevenson reports that junior water users who were participants in the Big Wood project are currently experimenting with several strategies developed in the project's policy scenarios narratives. These strategies include: using more efficient irrigation technology; planting new crops that use less water; and improving soil heath to increase water retention. Bill Hazen, a retired extension agent and Big Wood project participant, also recently commented that despite all the water issues and conflict in the Big Wood Basin that he feels that CIRC's Big Wood Alternative Futures results are widely accepted in the region for their credibility and that this is due in large part to CIRC's co-production process that relied heavily on stakeholder participants during development and validation of the modeling work.

Coordinated multi-state drought planning

State drought planners from Oregon, Washington, Idaho, and Montana convened in Boise in September 2016 to discuss shared drought triggers and indicators and planning. State climatologists, CIRC, the Western Regional Climate Center, and the National Drought Mitigation Center (NDMC) were also in attendance. The group met to discuss indicators and triggers for drought in the Pacific Northwest, but agreed to start with a shared drought impacts web-based reporter tool which will be developed with the help of NDMC.

13. Summary of NIDIS-Coping with Drought Efforts

CIRC is collaborating with NIDIS on the Pacific Northwest Drought Early Warning System (PNW DEWS), which formally launched in February 2016 in Portland, Oregon. CIRC activities during the past year supported the development of the PNW DEWS through outreach and engagement, further development of the Northwest Climate Toolbox, and research using data mining and machine learning techniques to identify regional areas of water scarcity and stress.

In partnership with NIDIS and others, CIRC researcher Dello co-facilitated the PNW DEWS Drought Indicators and Triggers Workshop in Boise, Idaho on September 26–27, 2016. The workshop brought together a select group of drought coordinators, planners, and climatologists from across the region to explore how indicators and triggers can be more effectively integrated into state drought plans to better forecast, monitor and respond to drought. Oregon, Washington, Idaho, and Montana agreed to approach drought in a similar way (e.g., coming up with similar indicators, triggers) despite different legal and regulatory nuances in how the various states respond to drought.

CIRC co-hosted a water year outlook in Boise, Idaho on November 10, 2016. The workshop was planned in conjunction with the Natural Resources and Conservation Service (NRCS) Idaho Snow Survey, Idaho Power, and the Idaho Department of Water Resources. In attendance were 70 water managers from eastern Oregon and western Idaho. The morning session included a standard outlook, with presentations from CIRC,

the National Weather Service (NWS), and NRCS. The afternoon session focused on relevant research from local academic and federal partners. CIRC plans on holding another such event in Idaho at the beginning of water year 2018.

CIRC co-convened a bi-monthly climate and drought outlook webinar series with the USDA Northwest Regional Climate Hub, NWS, and other partners (see section 10: ***Pacific Northwest Drought Early Warning System Webinars***).

In addition, Dello and CIRC's extension climate specialist Stevenson traveled across the region engaging stakeholders and raising awareness of the PNW DEWS. They engaged irrigators, growers, and extension agents in rural eastern Oregon, in Idaho, and within Oregon's state government. The Oregon State Legislature convened a drought task force in 2016 to perform a rapid study on tools and policies used by the state in times of drought. Dello presented an overview of the PNW DEWS to the Task Force, as well as the Oregon Drought Readiness Council. In addition, Dello keeps in close contact with the Washington Water Supply Availability Committee and has frequent DEWS-related and other conversations with chair, Jeff Marti.

During the past year, CIRC integrated the UW Drought Monitoring System for the Pacific Northwest, developed at the University of Washington, and climate tools developed at the University of Idaho into the Northwest Climate Toolbox (https://www.climatetoolbox.org). (See section 4: ***Climate and Water Toolbox Stream***.) CIRC researcher Abatzoglou presented the Toolbox during two of the PNW DEWS webinars (October, February). All of the webinars have included figures from the Toolbox. Figures from the Toolbox have been used in briefings to the Oregon state legislature and in stories with the media. CIRC is developing a survey for the Toolbox and is targeting specific user expert groups (the NWS climate focal points and fire weather leads, and FEMA, among others).

CIRC is researching and developing novel approaches with data mining and machine-learning techniques to identify areas in the Pacific Northwest that are most vulnerable to water scarcity and stress. During the past year, the analysis has increased the model's capacity to combine many disparate datasets and to find connections between climate and social impacts. This research will help CIRC identify potential communities to engage with and develop a new knowledge-to-action network around drought or fire hazards. (See section 4: ***Data Mining Stream***.)

CIRC researchers Amos and Lynn started working on drought planning with respect to tribes and legal matters. Amos and Lynn did preparatory work in anticipation of coordinating on drought planning and resilience. This work included creating a bibliography of resources identifying the regulatory and legal infrastructure pertinent to state and local level drought planning and response; identifying individuals and organizations to work with; and how to identifying ways to better integrate tribal knowledge and incorporate tribal sovereignty and decision-making authority in drought planning.

14. Project Database

See Attached Excel Document "2017 CIRC Project Database".

Appendix A. CIRC involvement in the Fourth National Climate Assessment (NCA4)

CIRC co-lead Mote and program manager Dalton are chapter authors of the Northwest chapter of the NCA4. Mote was selected as chapter lead, but stepped down after accepting the position of Associate Dean for Strategic Initiatives in the College of Earth, Ocean, and Atmospheric Sciences at Oregon State University, and continues with NCA4 as a chapter author. The two Northwest Regional Engagement Workshops on March 21, 2017 in Portland and March 23, 2017 in Boise were advertised through our *CIRCulator* list and targeted invitations were sent to some CIRC stakeholders. CIRC team member Lynn facilitates tribal-related NCA4 activities for the Pacific Northwest. Several CIRC publications are cited in the draft Northwest chapter.

Appendix B. June 2016-June 2017 CIRC Publications

Abatzoglou, John T., Daniel J. McEvoy, and Kelly T. Redmond. "The West Wide Drought Tracker: Drought Monitoring at Fine Spatial Scales." *Bulletin of the American Meteorological Society*, in press (2017). doi: 10.1175/BAMS-D-16-0193.1.

Abatzoglou, John T., Crystal A. Kolden, A. Park Williams, James A. Lutz, and Alistair MS Smith. "Climatic influences on interannual variability in regional burn severity across western US forests." *International Journal of Wildland Fire* 26 (2017): 269-275. doi: 10.1071/WF16165

Abatzoglou, John T., and **David E. Rupp**. "Evaluating climate model simulations of drought for the northwestern United States." *International Journal of Climatology* (2017). doi: 10.1002/joc.5046

Abatzoglou, John T., and A. Park Williams. "Impact of anthropogenic climate change on wildfire across western US forests." *Proceedings of the National Academy of Sciences* 113, no. 42 (2016): 11770-11775. doi: 10.1073/pnas.1607171113

Bachelet, Dominique, Timothy Sheehan, Ken Ferschweiler, and **John T. Abatzoglou**. "Simulating Vegetation Change, Carbon Cycling, and Fire Over the Western United States Using CMIP5 Climate Projections." In *Natural Hazard Uncertainty Assessment*, ed. Karin Riley et al. 257–75. Hoboken: John Wiley & Sons, 2016. doi: 10.1002/9781119028116.ch17.

Balch, Jennifer K., Bethany A. Bradley, **John T. Abatzoglou**, R. Chelsea Nagy, Emily J. Fusco, and Adam L. Mahood. "Human-started wildfires expand the fire niche across the United States." *Proceedings of the National Academy of Sciences* (2017): doi: 10.1073/pnas.1617394114

Barbero, Renaud, **John T. Abatzoglou**, and **Katherine C. Hegewisch**. "Evaluation of statistical downscaling of North American Multi-Model Ensemble forecasts over western USA." *Weather and Forecasting* (2016). doi: 10.1175/WAF-D-16-0117.1

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